

Worked Examples and Exercises in PRESENCE

These notes are to be used in conjunction with the workshop notes.

Contents

Introduction	3
The First Step – starting a new project and getting your data into PRESENCE.....	3
Next Step: Getting Some Estimates.	8
Stepping it up: using the custom models.....	15
Exercise 1	22
Fitting models with covariates.....	22
Exercise 2	29
Predicting Occupancy at Other Units.....	30
Sample Size Investigations.....	31
Multi-season models – a first example.....	33
Exercise 3	37

Introduction

PRESENCE is software that has been primarily developed fit occupancy models to detection/nondetection data. The basic sampling situation envisioned for all of these models is that within a landscape appropriately define sampling units are surveyed for a species to establish its presence/absence, but due to imperfect detection each 'survey' consists of multiple surveys of the sampling unit. The detection/nondetection of the species in each of the multiple surveys is recorded providing the necessary information to separate out false and true absences.

It has been purposely designed to resemble Program MARK to lessen the learning curve for users familiar with this popular mark-recapture software. A user can fit multiple models to their data set and PRESENCE stores the results for each model and presents a summary of how well the models rank according to a model selection metric (AIC is used as the default). Models are fit using maximum likelihood techniques, hence parameter estimates are known as *maximum likelihood estimates*.

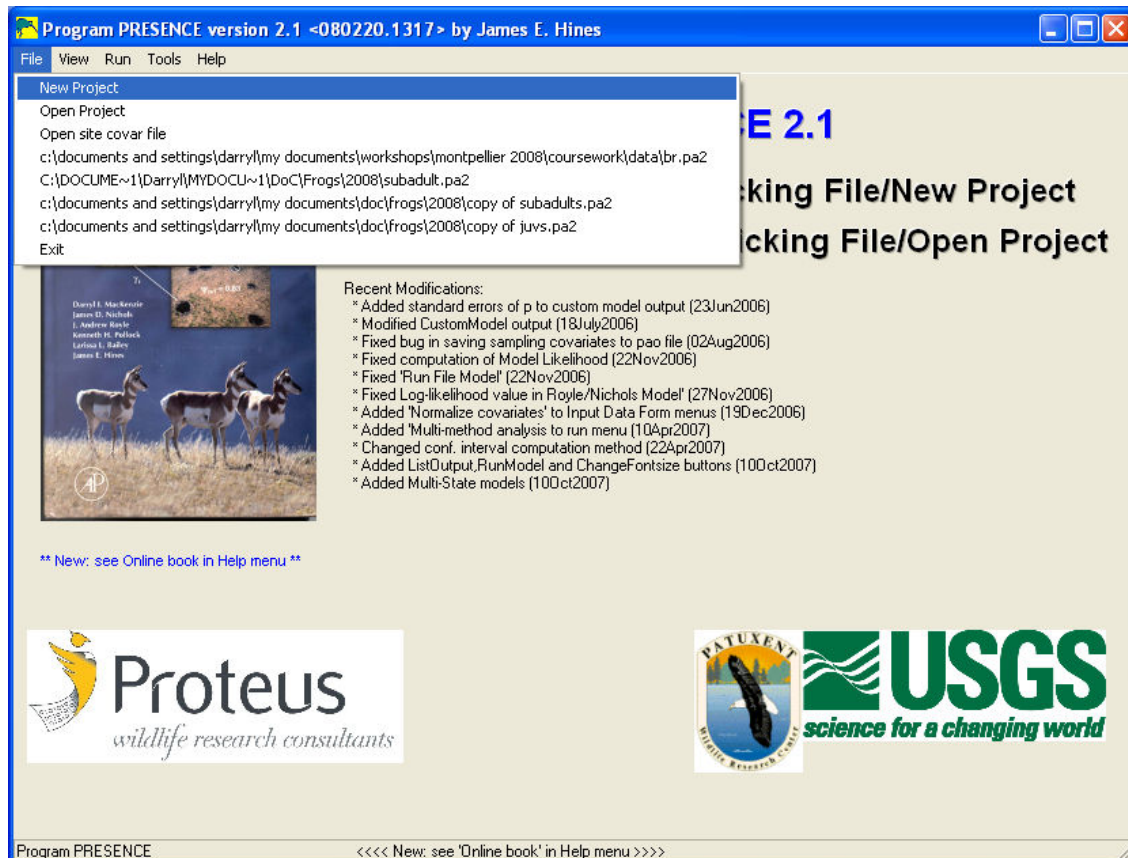
PRESENCE consists of 2 main windows; 1) a typical Windows graphical user interface (GUI); and 2) a CMD window (reminiscent of a DOS-window if your can remember back that far) that performs the number crunching. The entire analysis can be conducted using the GUI window, with the CMD window displaying progress on the model fitting procedure. This is useful as the CMD window indicates the current iteration number for the maximization routines (so it should be increasing, possibly slowly, if PRESENCE hasn't hung) and will sometimes contain hints for 'when things go wrong'.

The analysis results are stored as a *project*. Each project consists of 2 files, a data file: *.pao; and a results file: *.pa2. The data file is a tab-delimited text file with a specified format. These can be easily created external to PRESENCE, and then imported when a new project is begun, or inputted directly into PRESENCE using a spreadsheet-like interface. The results file contains the results for all models that have been fit to the data, and is given the same base filename as the data file.

The First Step – starting a new project and getting your data into PRESENCE

Here we're going to start a new project using one of the sample data sets that is installed along with PRESENCE. The data set is for the blue-ridge two-lined salamander (*Eurycea wilderae*) that was sampled at 39 transects, with 5 surveys per transect. For further details see page 99 of MacKenzie et al. (2006). We imagine that in most cases people will have their data stored in a format similar to this example, or would be able to get it into this format relatively easily. As a last resort, the data can be entered manually if need be.

Once you have started PRESENCE, in the menu bar, select **File>New Project**.



This will bring up a dialog window entitled “Enter Specifications for PRESENCE Analysis”, and you should select the large “Input Data Form” button in the bottom left corner.

Enter Specifications for PRESENCE Analysis

Notes

Data type not needed - just select type from Run menu

Royle models are now in 'Run' menu

Title for this set of data

Enter data filename Click to select file Click to view file

Results filename

No. Sites 20 No. Occasions/season 4

No. Site Covariates 0

No. Sampling Covariates 0

Cancel OK

Input Data Form

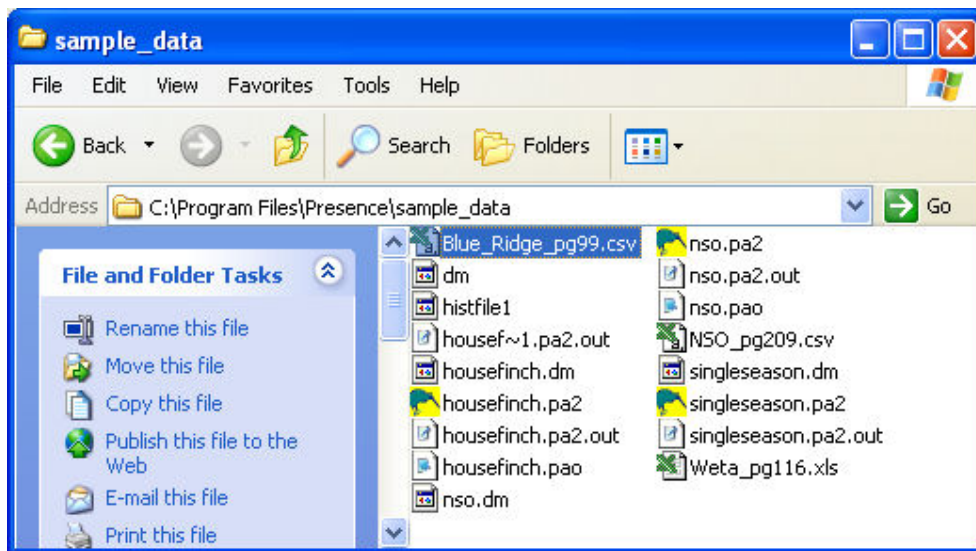
Select this button to open the Data Input Form window.

This, in turn, will open a data input interface window that allows you to copy and paste your data into PRESENCE from a spreadsheet package. The Data Input Form has a spreadsheet-like format. The detection/nondetection data or covariate values are entered into the respective grid cells, with the five text boxes near the top of the window being used to define

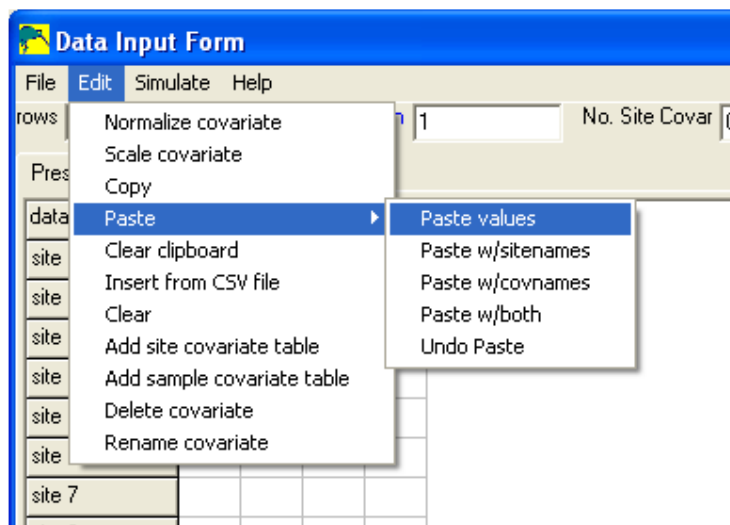
the various dimensions of the spreadsheet; the number of rows (sampling units; **A**), number of cols (repeated surveys; **B**), number of survey occasion per season (**C**), number of site-specific covariates (**D**) and number of sampling or survey-specific covariates (**E**). For this example there are no covariates, so we'll leave the last 2 boxes as '0', and PRESENCE will automatically adjust the number of rows and columns when we paste in the data. When running a single-season model (as in this example), PRESENCE will ignore the value in box **C**, however it's good practice to enter the number of columns associated with each seasons data in a comma delimited list. If you don't understand that at present, all will become clearer later.

data	1-1	2-1	3-1	4-1
site 1				
site 2				
site 3				
site 4				
site 5				
site 6				
site 7				
site 8				
site 9				
site 10				
site 11				
site 12				
site 13				
site 14				
site 15				
site 16				
site 17				
site 18				
site 19				
site 20				

Now we want to open the data file in our spreadsheet program, and paste the data into PRESENCE. In the PRESENCE installation folder (e.g., c:\program files\PRESENCE\)) there will be a folder called **sample_data**, within which is the data file for this example **Blue_Ridge_pg99.csv**.



From within your spreadsheet package, or by exploring **My Computer**, open this file. The data should appear as a series of 1's and 0's arranged in 39 rows (1 for each transect) and 5 columns (1 for each survey). It is presumed that your data is in a form where each row represents a site or sampling unit, and in each column is the result of the repeated detection/nondetection surveys for each unit. Select the entire data range (i.e., from cell A1-E39) and copy to the clipboard, then return to the **Input Data Form** (note you may need to locate the window in your task bar) and select **Edit>Paste>Paste Values** from the Edit menu.



The detection/nondetection data should now appear in the grid cells, with the number of rows and number of columns being automatically updated to 39 and 5 respectively. It's recommended that you manually enter that the number of occasions per season is 5. Once you've done this, the top portion of your Data Input Form should look like this:

data	1-1	1-2	1-3	1-4	1-5
site 1	0	0	0	1	1
site 2	0	1	0	0	0
site 3	0	1	0	0	0
site 4	1	1	1	1	0
site 5	0	0	1	0	0
site 6	0	0	1	0	0

Finally, before proceeding you need to save your data to a suitable location with an appropriate name in the usual manner by selecting **File>Save As**. When you do so, a message box will appear asking whether you want to use the last column of the detection data as frequency data (time of time which history was observed). Select **No**. The extension for a PRESENCE data file is *.pao* which will automatically be added to the filename.

Once saved, you can close the Data Input Form and return to the Enter Specifications window. Hit the “Click to select file” button, browse for and then select the data file you’ve just saved (I called it **pg_99.pao**). After you have selected the detection data file, the full filename and pathway will appear in the middle text box and the project filename will be shown in the third text box. The naming convention for the project file is to use the same base filename as the data file, but to change the extension to *.pa2*. This is important as if you want to reanalyse the same data set, but retain the results of a previous analysis, you first want to create a copy of the data file otherwise PRESENCE will attempt to overwrite the previous project file (although you will be prompted as to whether you want to overwrite the project first). The project title in the first text box is simply for your own reference and can be anything. The default is that the data filename is used for the project title. On the Enter Specifications window, once you’ve selected the data file, summary information is presented on the number of sites, number of surveys, etc. In a previous version you modified these values here rather than on the Data Input Form, but this information has been retained here to provide a double check that you’ve selected the right file. You also have the option of viewing the raw *.pao* file, which is just a tab delimited file with a specific layout.

Enter Specifications for PRESENCE Analysis

Project title: file=c:\program files\presence\sample_data\pg_99.pao

Data type not needed - just select type from Run menu

Royle models are now in 'Run' menu

Detection data filename: c:\program files\presence\sample_data\pg_99.pao

Project filename: Results filename: c:\program files\presence\sample_data\pg_99.pa2

No. Sites: 39 No. Occasions/season: 5

No. Occasions: 5

No. Site Covariates: 0

No. Sampling Covariates: 0

Buttons: Cancel, OK, Input Data Form

Annotations:

- Project title
- Detection data filename
- Project filename
- Summary information about data set that has been read in by PRESENCE
- Select this button once you are ready to create your project and begin the analysis.

In order to create the project file and proceed with the analysis, you must hit 'OK'. After doing so, the Enter Specifications window should close and be replaced with the Results Browser window. **If the Results Browser window does not appear, you have not created the project file and must repeat the above steps.**

Results Browser (pg_99.pa2)

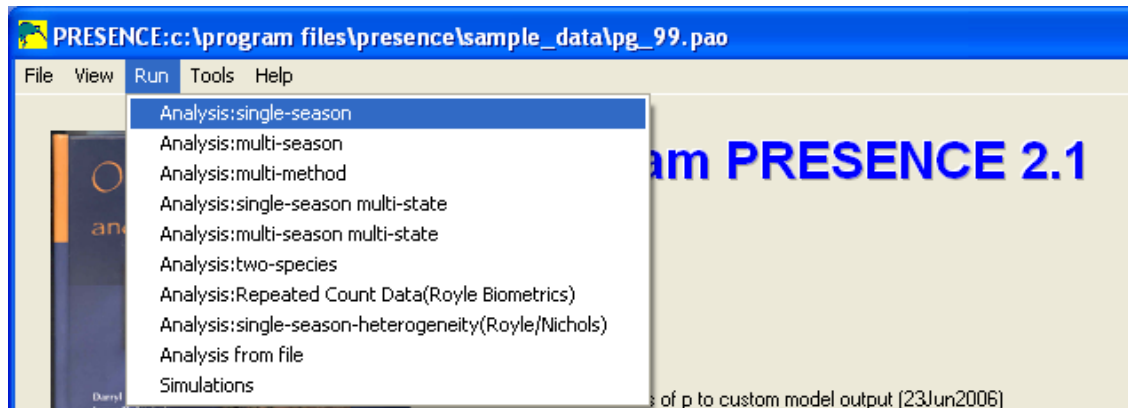
Model	AIC	deltaAIC	AIC wgt	Model Likelihood	no.Par.	-2*LogLike

Congratulations! Your data has been inputted, project file created and now you're ready to begin your analysis.

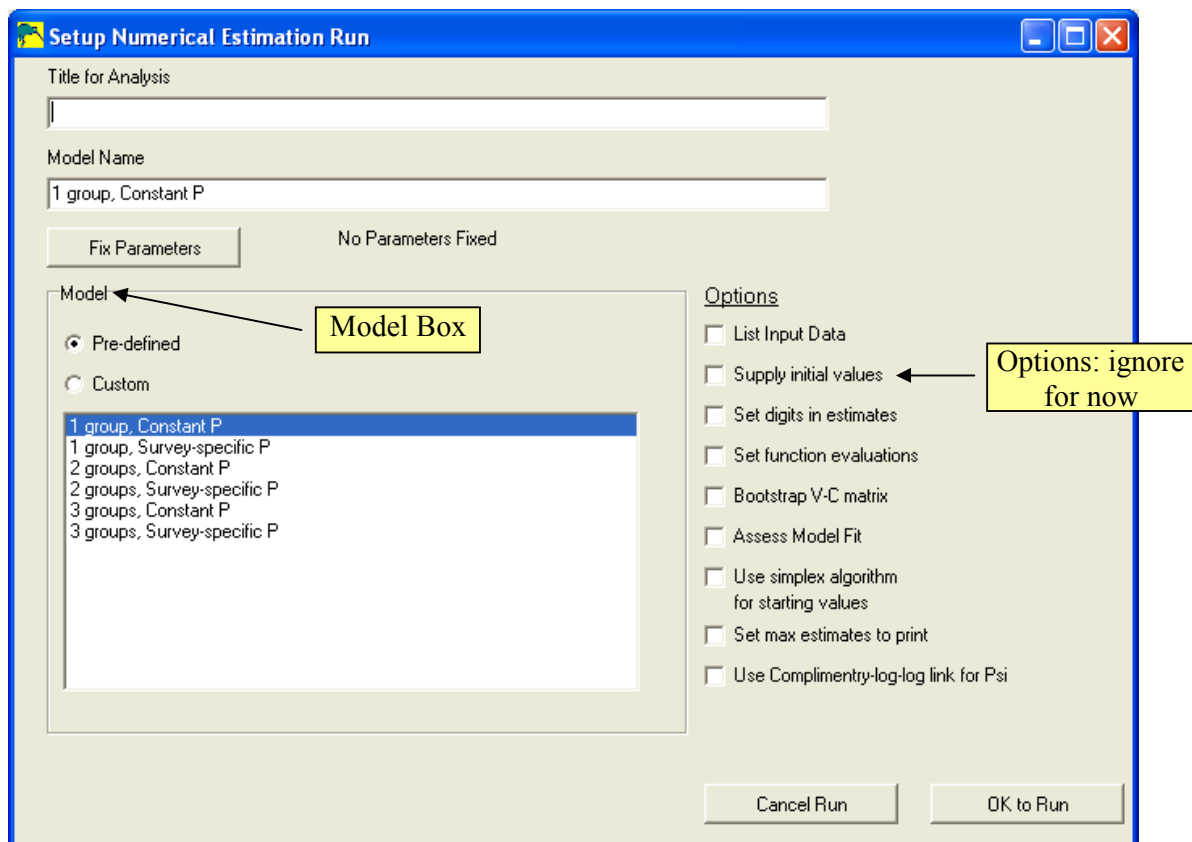
Next Step: Getting Some Estimates.

Here we are going to fit some single-season models to the blue-ridge salamander data that we have just set up the project for above. If you happened to have closed PRESENCE after creating the project file you can reopen the project by selecting **File>Open Project** from the

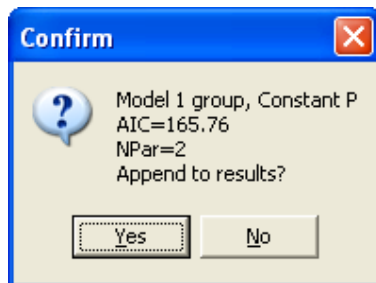
main PRESENCE window. Note that recent projects are also listed down the bottom of the **File** menu.



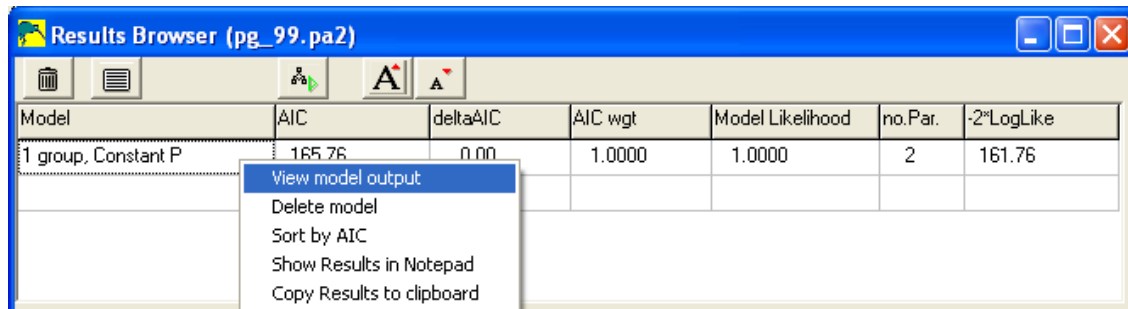
To run a single-season analysis, in the main PRESENCE window select **Run>Analysis: single-season**. This will bring up the **Setup Numerical Estimation Run (SNER)** window. This same window is used for all analyses, only the **Model** box varies between the different types of analyses. The other parts of the SNER window include the analysis title (which should be carried over from the title given when the project was created), model name, the ability to fix real parameter values, and various options that we shall ignore for now.



Within the model box, there are 2 options, Pre-defined or Custom. By default the pre-defined option is selected which provides a list of 6 pre-defined models that users can select to learn how to use PRESENCE, but generally will be of limited use for a full-blown data analysis (see the **Help** documentation for a definition of these models). In this example, we are going to fit the first 2 pre-defined models to the data, then fit the same 2 models using the Custom model and compare the outputs. The first model is estimating the same occupancy probability for all transects, and that detection probability (p) is constant across both transects and survey occasions (i.e., only 2 parameters will be estimated). The second model again assumes that all transects have the same probability of occupancy, but that p can vary between the five surveys although at each survey occasion, p is the same at all transects (i.e., 6 parameters will be estimated). So making sure the first pre-defined model is highlighted, hit the 'OK to Run' button (you may need to enter a title if this text box is blank). After a few micro-seconds, a message box should appear with some summary information about the results, asking you to confirm that you want these results added to the project file. Generally you would select 'Yes', as you should now.



When you do so, then the model name appears in the Results Browser, along with some other information that is largely uninteresting at this point as we have only fit 1 model to the data.



To view the results for this model, first **left-click** on the model name to select it, then **right-click** to open a pop-up menu (as indicated above), and then select **View model output**. The following output should appear in your default text editor (e.g., Notepad). The output begins with the model name, followed by some summary information about the data file and internal coding used by PRESENCE to define which model is being fit to the data. Following that there is some more summary information about the data file; number of groups assumed by predefined model (again, see **Help** for details), number of sites (transects in this case), etc. Following this we get into the more interesting part of the output. Reported is the number of parameters used to fit the model, twice the negative log-likelihood value evaluated at the maximum likelihood estimates (which is used to calculate AIC values or could be used in likelihood ratio tests), the AIC value for the model and the naïve estimate. The **naïve estimate** is the proportion of sites that were surveyed where the species was detected at least

once, which one would use as the estimate of the occupancy probability (ψ) without correcting for detection probability.

```

pres5554.tmp - Notepad
File Edit Format View Help
===== (1 group, Constant P) =====
|
PRESENCE - Presence/Absence-Site occupancy data analysis
Wed Mar 05 16:05:21 2008, version 2.1080209
-----
==>i=c:\program files\presence\sample_data\pg_99.pao
==>l=c:\program files\presence\sample_data\pg_99.pa2.out
==>name=1 group, Constant P
==>model=11c
==>lmt=200
model=11c N,T-->39,5
modtype-->1 Single-Season data Model selected

Data checksum = 29349
NSi-->0
NSa-->0
-----
no title
-----
modtype=1 N=39 T=5 Groups=1 bootstraps=0
-->0
*****

Predefined Model: Detection probabilities are NOT time-specific

Number of groups           = 1
Number of sites             = 39
Number of sampling occasions = 5
Number of missing observations = 0

Number of parameters        = 2
-2log(likelihood)           = 161.758589
AIC                         = 165.758589
Naïve estimate              = 0.461538

Proportion of sites occupied (Psi) = 0.5946 (0.1225)
Probability of group membership (Theta) = 1.0000 (0.0577)
Detection probabilities (p):
  grp  srvy    p      se(p)
  ---  ---    -  -
    1    1  0.258729 ( 0.057673)

Variance-Covariance Matrix
  psi  p(G1)
  0.0150 -0.0038
 -0.0038  0.0033
-----
CPU time: 0.0 seconds

```

Model name

Summary information

More summary information about the data

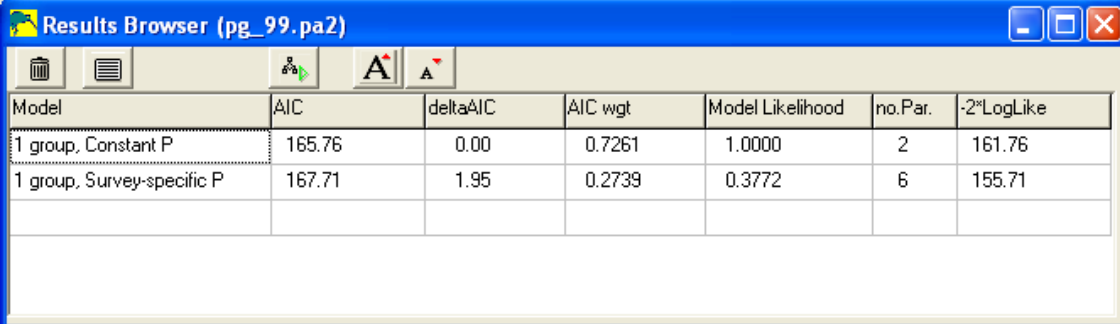
Estimate

SE

Below the naïve estimate are the estimated parameter values from the model. Ψ (ψ) is the probability of occupancy with the standard error (SE) given in parentheses, θ (θ) is the probability of group membership which is 1.0 in this case because we selected the predefined model with only 1 group. Next on the output are the estimated detection probabilities. In this

predefined model, detection probability was constant for all 5 surveys, so only a single estimate is presented that is the same for all 5 survey occasions. Finally is the variance-covariance matrix which can be used in association with the delta method to obtain standard errors for transformations of parameters. At this point simply note that the values on the main diagonal (top left to bottom right) are the variances for the estimated parameters; if you take the square-root of these values you obtain the reported standard errors.

The next step is to fit the second predefined model “**1 group, Survey-specific p**” using the same procedure as before, but selecting the second model in the pre-defined list and hitting ‘OK to Run’. After confirming this second model, your results browser should now look like this.



Model	AIC	deltaAIC	AIC wgt	Model Likelihood	no.Par.	-2*LogLike
1 group, Constant P	165.76	0.00	0.7261	1.0000	2	161.76
1 group, Survey-specific P	167.71	1.95	0.2739	0.3772	6	155.71

With 2 models now having been fit in our project, the results browser is more interesting so let's work through it. The results browser provides us with a summary of all the models that have been fit to the data in the project. PRESENCE ranks the models in terms of Akaike's Information Criterion (AIC). We are not going to go into details of what AIC is here (see Burnham and Anderson, 2002; or Google it), but will say it is a method for ranking models in order of parsimony. There are 7 columns in the results browser, each presenting a piece of summary information about the model, and how it ranks compared to others in the set. **Model** is obviously the name that was specified for each model; **AIC** is the AIC value for each model; **deltaAIC** is the relative difference in AIC values between each model and the currently top-ranked model (the one with smallest AIC); **AIC wgt** is the AIC weight which is a measure of support for each model being the 'best' model; **Model Likelihood** is the ratio of each models AIC weight over the model weight for the top-ranked model; **no. Par** is the number of parameters in the model; and **-2*LogLike** is twice the negative log-likelihood evaluated at the maximum likelihood estimates (MLEs).

Examining the results, a difference of only 1.95 AIC units between these 2 models indicates that even though it is not 'the best', the second model still has a reasonable level of support and there is further evidence of this with the second model having a substantial amount of AIC weight. Thus, while most of the evidence point towards the probability of detection being constant, the evidence is not overwhelming and there is some indication that the probability of detection varies between surveys. Alternatively, one could use these results to perform a likelihood ratio test of the null hypothesis of detection probability being constant, and the alternative hypothesis being that detection probability varies between surveys. The test statistic for this is $161.76 - 155.71 = 6.05$, which we would compare to the chi-square distribution with $6 - 2 = 4$ degrees of freedom, resulting in a p-value of 0.195 so there is insufficient evidence to reject the null hypothesis.

Opening the output for the second model, note that the same layout has been used as for the first model. The only major difference is towards the bottom of the output where rather than just the one estimate of detection probability being reported, there are now 5. Note there is a large degree of variation in the estimated values of p , and that the likely reason this model does not have greater support is the small sample sizes.

```

File Edit Format View Help
===== (1 group, Survey-specific P) =====

PRESENCE - Presence/Absence-Site Occupancy data analysis
Fri Mar 14 17:03:00 2008, version 2.1080209
-----
==>i=c:\program files\presence\sample_data\pg_99.pao
==>l=c:\program files\presence\sample_data\pg_99.pa2.out
==>name=1 group, Survey-specific P
==>model=11t
==>lmt=200
model=11t N,T-->39,5
modtype-->1 Single-Season data Model selected

Data checksum = 29349
NSi-->0
NSa-->0
-----
no title
-----
modtype=1 N=39 T=5 Groups=1 bootstraps=0

-->0
*****

Predefined Model: Detection probabilities are time-specific

Number of groups           = 1
Number of sites            = 39
Number of sampling occasions = 5
Number of missing observations = 0

Number of parameters       = 6
-2log(likelihood)          = 155.714832
AIC                        = 167.714832
Naive estimate              = 0.461538

Proportion of sites occupied (Psi) = 0.5813 (0.1179)
Probability of group membership (Theta) = 1.0000 (0.0861)
Detection probabilities (p):
  grp  srvy      p      se(p)
  ---  ---
    1     1  0.176166 ( 0.086095)
    1     2  0.133349 ( 0.072808)
    1     3  0.397067 ( 0.120510)
    1     4  0.353968 ( 0.111301)
    1     5  0.264348 ( 0.103247)

Variance-Covariance Matrix
  psi  p1(G1)  p2(G1)  p3(G1)  p4(G1)  p5(G1)
0.0139 -0.0031 -0.0001 -0.0057 -0.0037 -0.0044
-0.0031 0.0074 0.0003 0.0020 0.0015 0.0014
-0.0001 0.0003 0.0053 0.0006 0.0005 0.0004
-0.0057 0.0020 0.0006 0.0145 0.0030 0.0029
-0.0037 0.0015 0.0005 0.0030 0.0124 0.0021
-0.0044 0.0014 0.0004 0.0029 0.0021 0.0107
-----
CPU time: 0.0 seconds

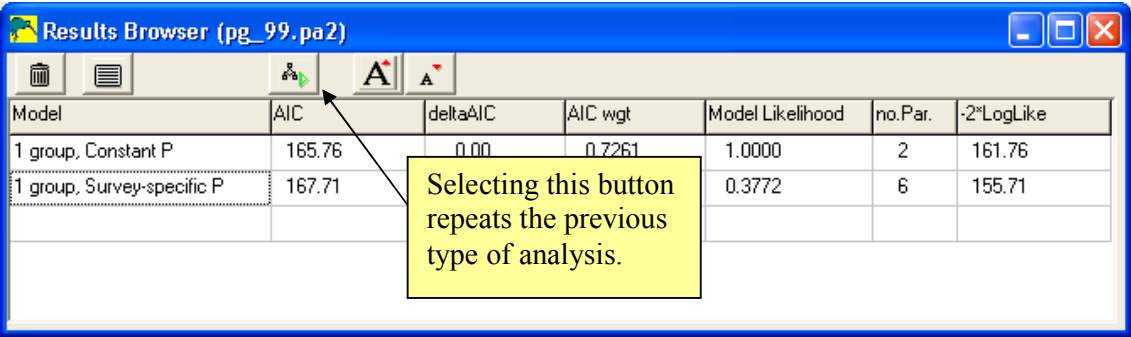
```

Finally, note that for both models, the estimated occupancy probability is very similar; 0.595 and 0.581 from the first and second models respectively. Hence, even though there is no clear indication of which model is the ‘best’, when interest is on estimating the probability of

occupancy, both models give essentially the same results, and both are 26% larger than the naïve estimate suggestion that the blue-ridge salamander was never detected at 1 in every 4 occupied transects.

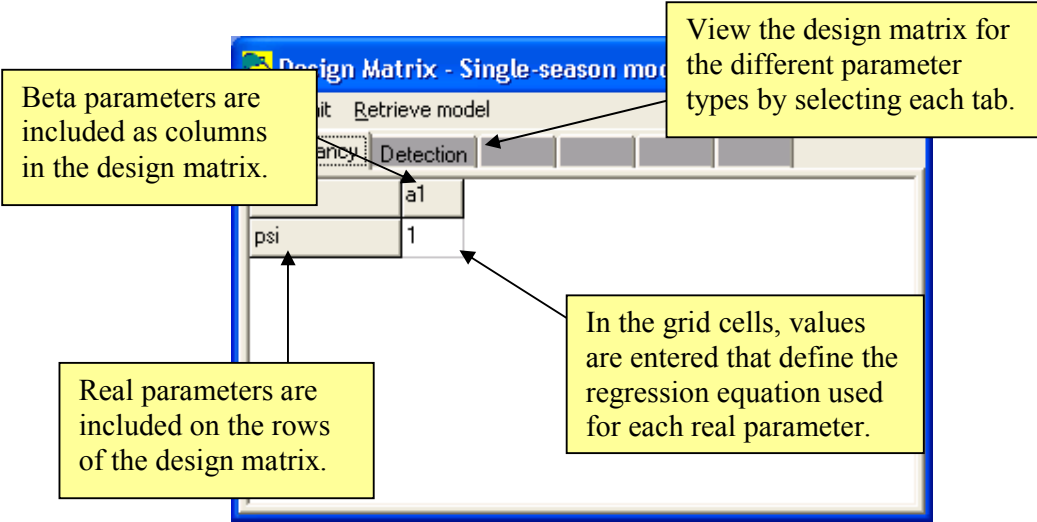
Stepping it up: using the custom models

Continuing with this example, we shall now fit the same models as above, but using the custom model option. Once again we can begin a single-season analysis from the run menu, or alternatively we can repeat the previous type of analysis by clicking on the button with the green triangle towards the top of the results browser (this will be greyed out if no previous analysis has been conducted in this session).



Model	AIC	deltaAIC	AIC wgt	Model Likelihood	no.Par.	-2*LogLike
1 group, Constant P	165.76	0.00	0.7261	1.0000	2	161.76
1 group, Survey-specific P	167.71			0.3772	6	155.71

Selecting the Custom radio button in the Model box in the SNER brings up the Design Matrix window. The design matrix is used to specify what factors you want to include in the model for each parameter type. Unlike Program MARK, in PRESENCE, the design matrix for each parameter type is given a separate sheet, and in the single-season model there are 2 parameter types: Occupancy and Detection probabilities.



	psi	a1
1		

Each row of the design matrix represents a real parameter, e.g., occupancy and detection probabilities. The columns represent the beta parameters: these are the parameters that are actually estimated by the algorithm that is attempting to maximise the likelihood and are the coefficients in the regression equation that is created when values are inputted to the grid cells in the design matrix. It should be remembered that there is a 3rd dimension to the design

matrix that drills back into the computer screen, namely the sampling units. Therefore, if a numeric value is entered into the design matrix, that value is applied to all sampling units. If a covariate name is entered into a grid cell, the value of that covariate for each sampling unit is used in the regression equation. We'll see examples of this later. The way one reads a design matrix is to move along each row and sum the terms that result from multiplying the value in the cell by the corresponding beta parameter. For example, the above design matrix defines the following logistic regression equation for the occupancy probability:

$$\begin{aligned}\text{logit}(\psi_i) &= 1 \times a_1 \\ &= a_1\end{aligned}$$

That is, the probability that a sampling unit (transects in this example) is occupied is the same for all sampling units, the logit of which will be estimated as a_1 . For the remainder of this example we are going to leave the design matrix for occupancy unchanged.

Next, select the tab labelled 'Detection' and note there are now 5 rows in the design matrix, each one corresponding to the probability of detection in each of the 5 surveys (in general there will be one row in the detection design matrix for each survey). For this design matrix there are 5 corresponding logistic regression equations:

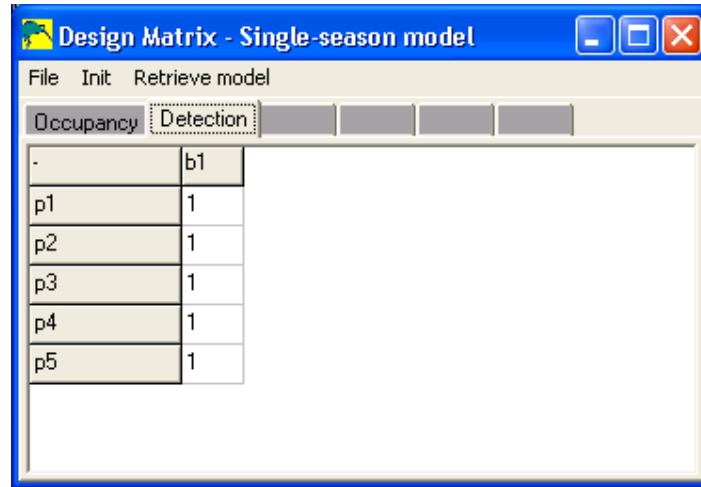
$$\text{logit}(p_{i1}) = 1 \times b_1 = b_1$$

$$\text{logit}(p_{i2}) = 1 \times b_1 = b_1$$

$$\text{logit}(p_{i3}) = 1 \times b_1 = b_1$$

$$\text{logit}(p_{i4}) = 1 \times b_1 = b_1$$

$$\text{logit}(p_{i5}) = 1 \times b_1 = b_1$$



	b1
p1	1
p2	1
p3	1
p4	1
p5	1

So in effect, this design matrix represents a model where detection probability is the same for all 5 surveys, the logit of which equals an amount b_1 . Therefore, this model is equivalent to the first predefined model: there is a single occupancy probability for all transects, and detection probability is constant both in time and across transects. To run this model, return to the SNER window (you may need to navigate through your task bar to locate the correct window) and hit 'OK to Run'. After confirming the results, the Results Browser should now look similar to:

Results Browser (pg_99.pa2)						
Model	AIC	deltaAIC	AIC wgt	Model Likelihood	no.Par.	-2*LogLike
1 group, Constant P	165.76	0.00	0.4207	1.0000	2	161.76
psi(.),p(.)	165.76	0.00	0.4207	1.0000	2	161.76
1 group, Survey-specific P	167.71	1.95	0.1587	0.3772	6	155.71

Note that the results summary for the custom model we have just fit (denoted as psi(.),p(.)) is identical to the first predefined model, as it should be. However, opening the output for this custom model we'll see there are some differences. At the top of the output we again see the model name followed by some summary information. Below the summary information the design matrix for each parameter type is given.

```

pres8826.tmp - Notepad
File Edit Format View Help
|-----=(psi(.),p(.))-----|
|
| PRESENCE - Presence/Absence-site occupancy data analysis
| Sat Mar 15 00:12:15 2008,          version 2.1080209
| -----
| ==>i=c:\program files\presence\sample_data\pg_99.pao
| ==>l=c:\program files\presence\sample_data\pg_99.pa2.out
| ==>name=psi(.),p(.)
| ==>model=100
| ==>j=c:\program files\presence\sample_data\pg_99.dm
| ==>imt=200
| model=100 N,T-->39,5
| modtype-->1 Single-Season data Model selected
|
| Data checksum = 29349
| NSi-->0
| NSa-->0
| -----
| no title
| -----
| modtype=1 N=39 T=5 Groups=1 bootstraps=0
|
| -->0
|
| Matrix 1: rows=2, cols=2
| -,a1,
| psi 1
| =====
|
| Matrix 2: rows=6, cols=2
| -,b1,
| p1 1
| p2 1
| p3 1
| p4 1
| p5 1
| =====
|
| Custom Model:
|
| Number of sites          = 39
| Number of sampling occasions = 5
| Number of missing observations = 0

```

Following the design matrices there is some more summary information, as in the predefined model. The table titled ‘Untransformed Estimates of coefficients for covariates (Beta’s)’ presents the estimated beta parameters, with the label for each beta parameter in the leftmost column corresponding to those used in the design matrices. So here a_1 is estimated to be 0.383 with a standard error of 0.509, and b_1 is estimated to be -1.053 with standard error 0.301.

pres8826.tmp - Notepad

File Edit Format View Help

Custom Model:

Number of sites = 39
 Number of sampling occasions = 5
 Number of missing observations = 0

Number of parameters = 2
 -2log(likelihood) = 161.7586
 AIC = 165.7586

Model has been fit using the logistic link.

Naive estimate = 0.4615

Untransformed Estimates of coefficients for covariates (Beta's)

			estimate	std.error
A1	:occupancy	psi	0.383108	(0.508589)
B1	:detection	p1	-1.052585	(0.300851)

Variance-Covariance Matrix of Untransformed estimates (Beta's):

	A1	B1
A1	0.258663	-0.083279
B1	-0.083279	0.090511

estimates of Psi:

site	Survey	Psi	Std.err	95% conf. interval
1 site 1	1	0.5946	0.1226	0.3512 - 0.7990

Individual site estimates of p:

site	Survey	p	Std.err	95% conf. interval
1 site 1	1	0.2587	0.0577	0.1622 - 0.3863

DERIVED parameter - Psi-conditional

site	psi-cond	Std.err	95% conf. interval
1 site 1	0.2472	0.1472	-0.0413 - 0.5356

CPU time: 0.0 seconds

After the table is the variance-covariance matrix for the beta parameters, then the estimated occupancy and detection probabilities are presented. These values are calculated using the design matrices and the logit link. So recall that for occupancy the design matrix provides the equation (where the ‘hats’ indicate we now have estimated quantities):

$$\text{logit}(\hat{\psi}_i) = \hat{a}_1 = 0.383$$

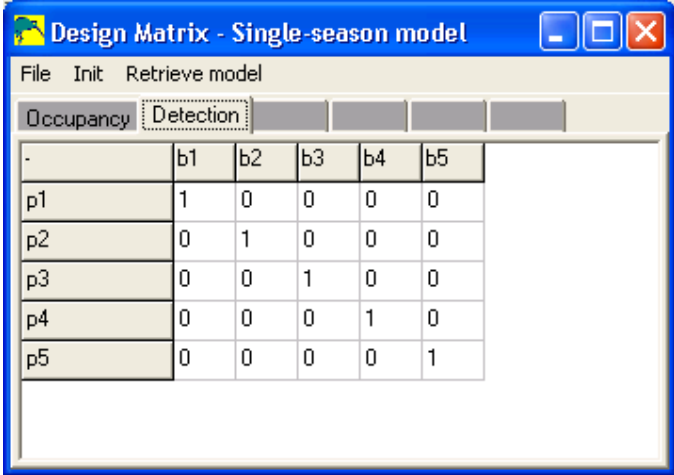
$$\hat{\psi}_i = \frac{e^{0.383}}{1 + e^{0.383}} = 0.595$$

The standard error for $\hat{\psi}_i$ is obtained using the delta method, which for this model is relatively simple because the transformed quantity of interest ($\hat{\psi}_i$) is only a function of 1 beta parameter.

$$\begin{aligned} \text{Var}(\hat{\psi}_i) &= (\hat{\psi}_i (1 - \hat{\psi}_i))^2 \text{Var}(\hat{a}_1) \\ &= (0.595 \times 0.405)^2 \times 0.259 \\ &= 0.015 \\ \text{SE}(\hat{\psi}_i) &= \sqrt{\text{Var}(\hat{\psi}_i)} \\ &= 0.123 \end{aligned}$$

A similar procedure is used to calculate the detection probability and its standard error. You should take a few minutes to compare the results to the first model we fit and note the same estimates are obtained. The final piece of the output on the custom model is a derived parameter: a quantity that is not directly in the model structure, but can be calculated from parameters that are. For the single-season model the derived parameter is the probability that a unit is occupied given that the species is never detected there. So in this example, if the species was not detected in any of the 5 surveys of a transect, what is the probability of blue-ridge salamanders being present there (see MacKenzie et al. 2006 for details).

To fit the equivalent of the **1 group, Survey-specific P** model, again select to run a custom, single-season model. Leave the design matrix for occupancy as the default option (as in the last model), and set the design matrix for detection probability to be as indicated below.



	b1	b2	b3	b4	b5
p1	1	0	0	0	0
p2	0	1	0	0	0
p3	0	0	1	0	0
p4	0	0	0	1	0
p5	0	0	0	0	1

A shortcut to creating this design matrix is to select the menu item **Init>Full Identity**. This creates the identity matrix which has as many columns as rows, with 1's on the main diagonal and 0's elsewhere. From this matrix we can write the following sets of equations.

$$\text{logit}(p_{i1}) = 1 \times b_1 + 0 \times b_2 + 0 \times b_3 + 0 \times b_4 + 0 \times b_5 = b_1$$

$$\text{logit}(p_{i2}) = 0 \times b_1 + 1 \times b_2 + 0 \times b_3 + 0 \times b_4 + 0 \times b_5 = b_2$$

$$\text{logit}(p_{i3}) = 0 \times b_1 + 0 \times b_2 + 1 \times b_3 + 0 \times b_4 + 0 \times b_5 = b_3$$

$$\text{logit}(p_{i4}) = 0 \times b_1 + 0 \times b_2 + 0 \times b_3 + 1 \times b_4 + 0 \times b_5 = b_4$$

$$\text{logit}(p_{i5}) = 0 \times b_1 + 0 \times b_2 + 0 \times b_3 + 0 \times b_4 + 1 \times b_5 = b_5$$

Note that the coefficients associated with each beta parameter in each equation correspond with the entries in the design matrix, and result in a model where the probability of detecting the salamanders in each of the 5 surveys will be estimated by a different beta parameter. Going back to the SNER window, before running the model we need to change the name of the model. So far we have simply used the default names for each model, but here we should enter something meaningful. Now model names are completely arbitrary and the main point to consider is that the model name is meaningful to you. However, we suggest that you follow a convention that is becoming widely used where each parameter type is listed, and in parentheses the factors that affect that parameter are listed.

Here, there are no factors influencing occupancy probability (it is the same for all transects) which is denoted as 'psi(.)', and detection probability is different for each survey hence 'p(Survey)'. After renaming the model, hit 'Ok to Run', and after confirming the results, your results browser should now look like as below where the summary information for the model **psi(.), p(Survey)** is the same as the predefined model, **1 group, Survey-specific P**.

Results Browser (pg_99.pa2)						
Model	AIC	deltaAIC	AIC wgt	Model Likelihood	no.Par.	-2*LogLike
1 group, Constant P	165.76	0.00	0.3631	1.0000	2	161.76
psi(.).p(.)	165.76	0.00	0.3631	1.0000	2	161.76
1 group, Survey-specific P	167.71	1.95	0.1369	0.3772	6	155.71
psi(.).p(Survey)	167.71	1.95	0.1369	0.3772	6	155.71

Opening the output for this model we again see the initial summary information followed by the design matrices. Note the more complex design matrix for detection probability. Below the portion of the output starting from the table of beta parameter estimates is presented. Given the design matrix, the estimated beta parameters b_1 - b_5 represent the absolute probability of detecting salamanders at an occupied transect in each survey (on the logit-scale). The real parameter estimates are calculated in much the same way as for the previous custom model, based upon the defined design matrices and estimated beta parameters. Comparing these real parameter estimates to those obtained from the corresponding predefined model you will note they are very slightly different, which is due to the -2LogLike values actually being different in the decimal place, but the difference is effectively negligible.

pres1498.tmp - Notepad

File Edit Format View Help

Untransformed Estimates of coefficients for covariates (Beta's)

			estimate	std.error
A1	:occupancy	psi	0.322275	(0.482586)
B1	:detection	p1	-1.537688	(0.580492)
B2	:detection	p2	-1.877696	(0.643633)
B3	:detection	p3	-0.413967	(0.496702)
B4	:detection	p4	-0.602625	(0.497355)
B5	:detection	p5	-1.018563	(0.518256)

Variance-Covariance Matrix of Untransformed estimates (Beta's):

	A1	B1	B2	B3	B4	B5
A1	0.232889	-0.065148	-0.061829	-0.089069	-0.082975	-0.072988
B1	-0.065148	0.336971	0.031558	0.045462	0.042351	0.037254
B2	-0.061829	0.031558	0.414263	0.043146	0.040193	0.035356
B3	-0.089069	0.045462	0.043146	0.246713	0.057902	0.050933
B4	-0.082975	0.042351	0.040193	0.057902	0.247362	0.047448
B5	-0.072988	0.037254	0.035356	0.050933	0.047448	0.268589

Individual site estimates of Psi:

	Site	Survey	Psi	Std.err	95% conf. interval
1	site 1	1	1-1: 0.5799	0.1176	0.3490 - 0.7804

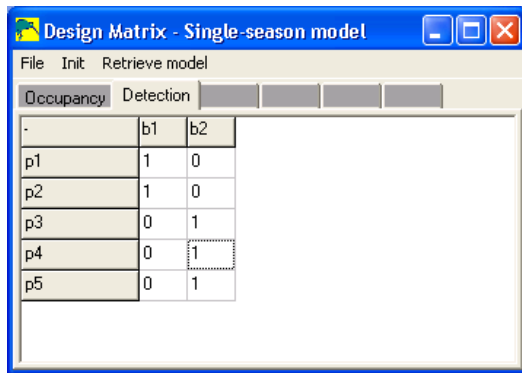
Individual site estimates of p:

	Site	Survey	p	Std.err	95% conf. interval
1	site 1	1	1-1: 0.1769	0.0845	0.0644 - 0.4013
1	site 1	2	1-2: 0.1327	0.0741	0.0415 - 0.3507
1	site 1	3	1-3: 0.3980	0.1190	0.1998 - 0.6364
1	site 1	4	1-4: 0.3537	0.1137	0.1712 - 0.5920
1	site 1	5	1-5: 0.2653	0.1010	0.1156 - 0.4993

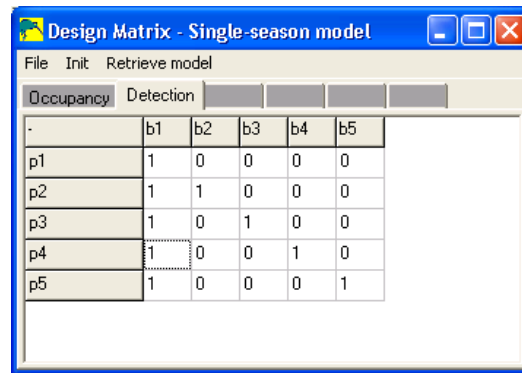
Following the real estimates for p , a brief histogram of these estimates is given as a visual summary of the result, with the last piece of the output being the derived parameter for the probability of occupancy given salamanders were never detected at a transect.

Exercise 1

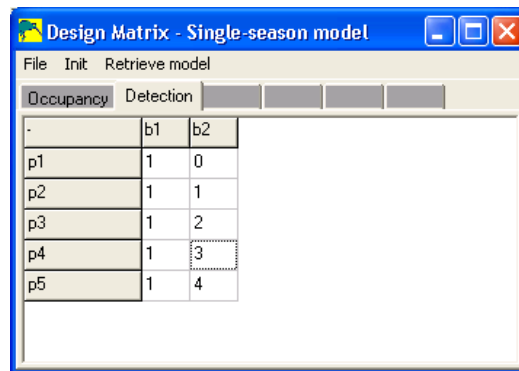
For the following three design matrices for detection probability; 1) write out the set of equations for detection probabilities; 2) fit the model; 3) describe what the model means in terms of variation in detection probability; and 4) interpret the result. In all cases maintain occupancy to be constant for all sites, i.e., a **psi(.)** model.



	b1	b2
-		
p1	1	0
p2	1	0
p3	0	1
p4	0	1
p5	0	1



	b1	b2	b3	b4	b5
-					
p1	1	0	0	0	0
p2	1	1	0	0	0
p3	1	0	1	0	0
p4	1	0	0	1	0
p5	1	0	0	0	1



	b1	b2
-		
p1	1	0
p2	1	1
p3	1	2
p4	1	3
p5	1	4

Hint: to add a column to the design matrix, right click the mouse button when over any cell to open a pop-up menu and select the appropriate option.

Fitting models with covariates

In this example we shall fit models that involve covariates for both occupancy and detection probabilities to data that has been collected on the Mahoenui giant weta in a scientific reserve by the Department of Conservation in the King Country district of New Zealand. 72 3m-radius circular plots were surveyed between 3-5 times for weta. Each plot was assessed as to the level of browsing by feral goats and each survey was conducted by 1 of 3 observers. See MacKenzie et al. (2006) for more details. The data is included in the sample data folder that is installed along with PRESENCE in the Excel spreadsheet **Weta_pg116.xls**. This file consists of 5 sheets containing the detection-nondetection data (**detection_histories**), whether a plot was browsed or unbrowsed (**site_covar**), and which observer conducted which survey

(**Obs1**, **Obs2** and **Obs3**). In this example the number of surveys is not constant for all plots hence the detection-nondetection data includes missing observations that are indicated with a “-“. Each of the covariates are dummy variables that =1 if the covariate is of the value indicated by the covariate name, and =0 otherwise. Note that continuous valued covariates are also possible.



Photo credit: Mahoenui giant weta, Amanda Smale, Department of Conservation.

Begin PRESENCE, start a new project and open the data input form. Copy and paste the detection-nondetection data from the spreadsheet into PRESENCE in the same manner as for the previous example, changing the number of surveys per season to 5. Next we have 2 site-specific covariates (whether a site was browsed or unbrowsed by the goats) and 3 sampling occasion, or survey-specific, covariates we want included in our data file. Therefore, change the number of site-specific covariates to 2 and the number of sampling covariates to 3. Note that when you do so additional tabs appear for sheets on which you enter your data. As the site-specific covariates must remain constant for the entire season, each one only requires 1 column hence all site-specific covariates are entered on a single sheet. The sampling occasion covariates can vary with each survey hence the covariate will have the same dimensions as the detection-nondetection data, hence 1 sheet is required by each sampling covariate.

rows 72 cols 5 No. Occ/season 5 No. Site Covar 2 No. Sampling Covar 3

Presence/Absence data Site Covars SampCov1 SampCov2 SampCov3

data	1-1	1-2	1-3	1-4	1-5
site 1	0	0	0	0	-
site 2	0	0	0	0	-
site 3	0	0	0	0	-
site 4	0	0	0	0	-
site 5	0	0	0	0	-

Number of site-specific covariates.

Number of sampling occasion covariates.

Note the additional tabs that appear.

To input the site-specific covariates, in your spreadsheet programme select the sheet labelled **site_covar**, highlight the range of the covariate data including the covariate names (i.e., cells A1:B73), copy the selected cells, return to PRESENCE's data input form and select the tab labelled **Site Covar**. Click on the top-left grid cell and make sure the cell border becomes a dotted line (not a flashing cursor), then from the edit menu, select **Edit>Paste w/covnames**. This paste option will not only paste the covariate values into the grid cells, but will also paste in the covariate names.

rows 72 cols 5 No. Occ/season 5 No. Site Covar 2 No. Sampling Covar 3

Presence/Absence data Site Covars SampCov1 SampCov2 SampCov3

sitecov	Browsed	Unbrowsed
site 1	1	0
site 2	1	0
site 3	1	0
site 4	0	1
site 5	1	0
site 6	0	1

Select this tab to enter site-specific covariates.

Note the dotted outline which indicates which cell/column is active.

The enter the sampling (or survey-specific) covariate that indicates whether observer 1 conducted the survey, return to your spreadsheet software and select the tab labelled **Obs1**, select and copy the values (cells A1:E72), return to the data input form and select the tab labelled **SampCov1**. Make the top-left cell active and paste the values by selecting **Edit>Paste>Paste values**. Next rename the covariate by selecting **Edit>Rename covariate** and in the text box insert **Obs1** and hit 'OK'. Repeat these steps for the covariates **Obs2** and **Obs3**.

Enter new name for SampCov1:

Obs1

OK Cancel

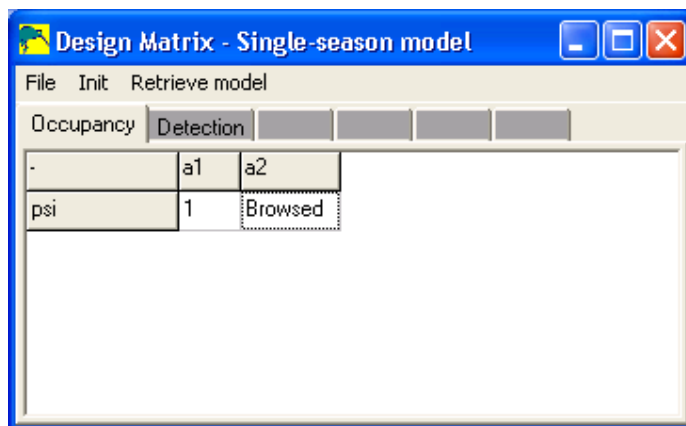
Note that the observer covariates contain missing values, and that these exactly correspond with the missing values in the detection-nondetection data. Covariate values are allowed to be missing, but only if the detection-nondetection data for the corresponding survey of the sampling unit is also missing. The assumption is required by most statistical methods. Missing values for site-specific covariates are not allowed.

Once you have entered all 3 observer covariates, save the data file using an appropriate name (here I have used 'weta_116') then close the data input form which will return you to the **Enter Specifications for PRESENCE Analysis** window. Select the data file you have just created, add a title for the project then select 'OK'. After a couple of seconds a blank results browser should appear. Remember, if you do not see the results browser, you have not successfully set up your project file.

Here we are going to follow the example on page 116 of MacKenzie et al. (2006), with details initially being provided for how to include covariates in a few simple models and fitting the remainder of the candidate model set being left as an exercise.

First, let's fit a simple model where the probability of occupancy is the same for all plots and the probability of detection is the same in all surveys. In our earlier notation we could call this model **psi(.),p(.)**. This is the same as the first custom model that we fit in the salamander example, so recall the design matrix for occupancy was just a '1' in the single grid cell, and for detection probability we have five rows (for the 5 possible survey occasions) and require a single column of '1's. This is actually the default model that appears where you select to run a custom, single-season model, hence after the design matrix appears you just need to hit 'Ok to Run' then confirm the results to add them to the results browser.

Next we shall fit a model where the probability of occupancy will vary between plots according to the level of browsing, and detection probability will be allowed to vary among days. We could call this model **psi(Browsed),p(Day)**. We shall first fit the model, then work back through it explaining what we're actually doing. So start the analysis by selecting **Run>Analysis:single-season** and clicking on the **Custom** radio button if it is not already selected. This will bring up the design matrices window and set the design matrix for occupancy to look like the following.



This will require you to add a column to the design matrix, then enter the respective covariate name. To add a column, you simply right-click anywhere on the design matrix which opens a

pop-up menu and select **Add Col** (the 5th item in the menu) which will create an empty column on the right-hand side of the design matrix. You can then either type the name of the covariate into the grid cell, but if you do so you must get the name 100% correct and PRESENCE is case sensitive. Alternatively, if you open the **Init** menu you will notice that all of the available covariates are listed there, prefixed with a '*'. After activating column 2 (so the grid cell in the second column has the dotted outline), select **Init>*Browsed** and the covariate name **Browsed** will be inserted into the correct column.

To define a model where detection probability varies among days, after selecting the detection tab, select **Init>Full identity** which will give:

	b1	b2	b3	b4	b5
p1	1	0	0	0	0
p2	0	1	0	0	0
p3	0	0	1	0	0
p4	0	0	0	1	0
p5	0	0	0	0	1

Once the design matrices are setup up, return to the SNER window (without closing the design matrix window), rename the model then hit 'OK to Run' and confirm the results when prompted.

So what have we just done? Lets start with the simple one; the design matrix for detection probability. Recall that we have already used this design matrix in the blue-ridge salamander example, and that to read the design matrices we move along the row, we sum the terms produced by multiplying the values in the grid cell with the corresponding beta parameters for each column. So here we could write the set of equations:

$$\text{logit}(p_{i1}) = 1 \times b_1 + 0 \times b_2 + 0 \times b_3 + 0 \times b_4 + 0 \times b_5 = b_1$$

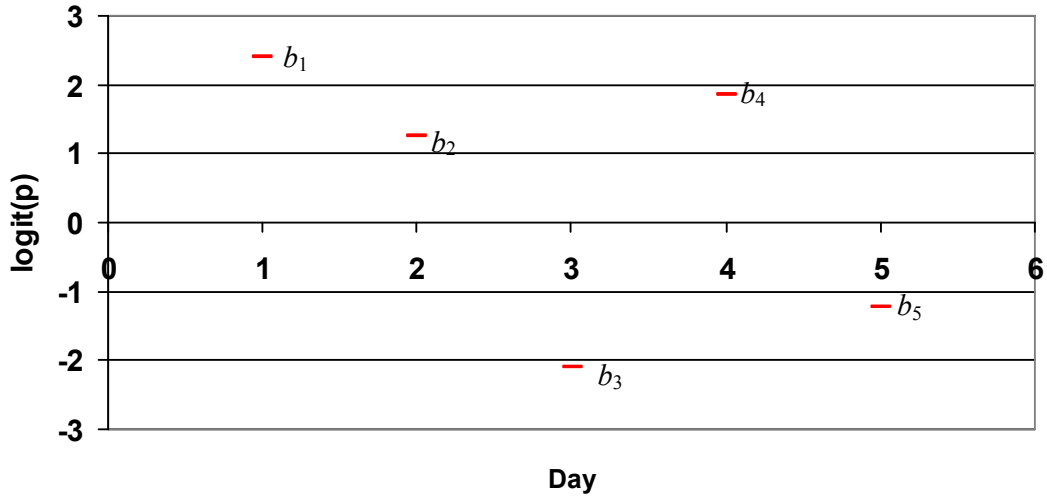
$$\text{logit}(p_{i2}) = 0 \times b_1 + 1 \times b_2 + 0 \times b_3 + 0 \times b_4 + 0 \times b_5 = b_2$$

$$\text{logit}(p_{i3}) = 0 \times b_1 + 0 \times b_2 + 1 \times b_3 + 0 \times b_4 + 0 \times b_5 = b_3$$

$$\text{logit}(p_{i4}) = 0 \times b_1 + 0 \times b_2 + 0 \times b_3 + 1 \times b_4 + 0 \times b_5 = b_4$$

$$\text{logit}(p_{i5}) = 0 \times b_1 + 0 \times b_2 + 0 \times b_3 + 0 \times b_4 + 1 \times b_5 = b_5$$

Or we could represent it graphically as:



So there are no constraints on how detection probability might vary among days; each day is free to have a unique value that is different to the others, and the logit of these values is b_1 - b_5 . That is, this design matrix represents the model that allows detection probability to be day specific, with all plots having the same probability on each day.

Next, let's consider the design matrix for the occupancy probability, which is a representation of the following equation.

$$\begin{aligned}\text{logit}(\psi_i) &= \mathbf{1} \times a_1 + \mathbf{Browsed}_i \times a_2 \\ &= a_1 + a_2 \times \mathbf{Browsed}_i\end{aligned}$$

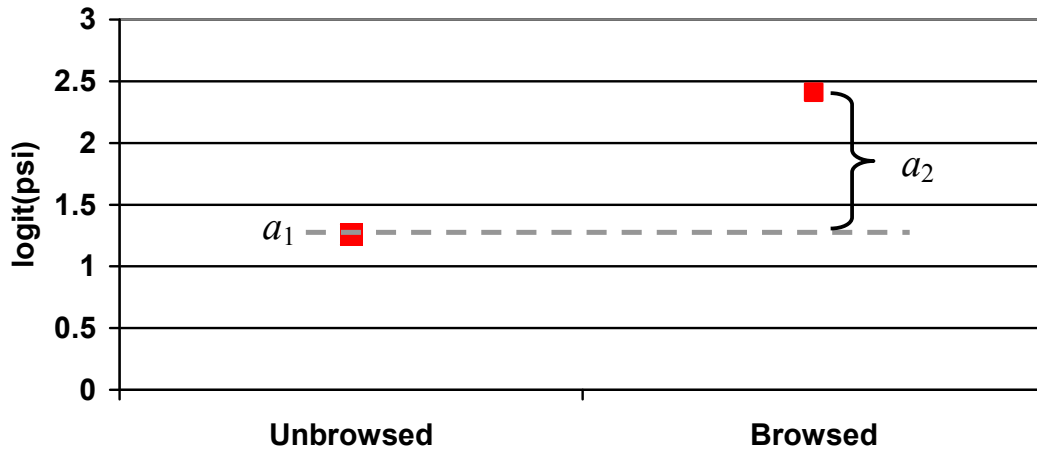
Recall that *Browsed* is a covariate that we defined such that if plot i showed signs of browsing = 1, and = 0 otherwise. Therefore, for an unbrowsed plot (where $\mathbf{Browsed}_i = 0$),

$$\begin{aligned}\text{logit}(\psi_i) &= a_1 + a_2 \times 0 \\ &= a_1\end{aligned}$$

and for a browsed plot (where $\mathbf{Browsed}_i = 1$),

$$\begin{aligned}\text{logit}(\psi_i) &= a_1 + a_2 \times 1 \\ &= a_1 + a_2\end{aligned}$$

Note that a_2 is therefore the difference in occupancy between a browsed and unbrowsed plot (on the logit scale), or alternatively what effect browsing has on occupancy compared to plots with no browsing. Graphically, we could represent this as:



Looking at the output from this model, $\hat{a}_2 = 1.24$ which, as it is >0 , indicates that the probability of occupancy is higher at browsed plots. In this fairly simple model we can interpret \hat{a}_2 in a fairly straightforward manner, although for more complicated models it can be useful to interpret the effect of a covariate in terms of an odds ratio. Using the logit link the odds ratio can be calculated as:

$$\begin{aligned} OR &= e^{\hat{a}_2} \\ &= e^{1.24} \\ &= 3.44 \end{aligned}$$

The interpretation of this would be that the odds of occupancy at a browsed site is 3.44 times larger for a browsed plot than an unbrowsed plot. An approximate 2-sided 95% confidence interval for the odds ratio would be:

$$\begin{aligned} &= (\exp(1.24 - 2 \times 0.787), \exp(1.24 + 2 \times 0.787)) \\ &= (e^{-0.27}, e^{2.74}) \\ &= (0.76, 15.49) \end{aligned}$$

Exercise 2

- Working in small groups, fit the model with the following design matrices. Write out the corresponding equations, draw the graphs and interpret the resulting beta parameter estimates. Fit the same model but with a different parameterization for both design matrices.

	a1	a2
psi	Unbrowsed	Browsed

	b1	b2	b3	b4	b5	b6	b7
p1	1	0	0	0	0	Obs1	Obs2
p2	0	1	0	0	0	Obs1	Obs2
p3	0	0	1	0	0	Obs1	Obs2
p4	0	0	0	1	0	Obs1	Obs2
p5	0	0	0	0	1	Obs1	Obs2

- Within your groups fit the following set of models to the weta data, and discuss the results.
 - $\psi(\cdot)p(\cdot)$
 - $\psi(\cdot)p(\text{Day})$
 - $\psi(\cdot)p(\text{Obs})$
 - $\psi(\cdot)p(\text{Day} + \text{Obs})$
 - $\psi(\text{Browsed})p(\cdot)$
 - $\psi(\text{Browsed})p(\text{Day})$
 - $\psi(\text{Browsed})p(\text{Obs})$
 - $\psi(\text{Browsed})p(\text{Day} + \text{Obs})$
- Calculate the summed AIC weights for the *Browsed* covariate for occupancy, and the *Observer* covariate for detection (**hint**: if you right mouse click on the **Results Browser** you can copy the table to the clipboard, and then paste into a spreadsheet).
- Calculate the model averaged estimate (and SE) of the probability of occupancy for a browsed plot.

Predicting Occupancy at Other Units

Once a model has been fit to the data, the resulting regression equation of species occurrence can be used to predict the probability of occupancy at other units based upon the values of the covariates that are in the equation that have been measured at the other units. You might be interested in doing so to build maps of species occurrence for example. For large problems it is likely to be most efficient to set the procedure up within software such as R or SAS, or write specific code to do so. However for smaller problems it is possible to trick PRESENCE into doing this prediction for you.

The secret is to add the required number of rows to the bottom of the detection data, with all surveys indicated as missing. By doing so, this will have no effect on the estimation of the parameter values. The site-specific covariate values for these ‘phantom’ units can be entered as normal, and the survey-specific covariates could also be entered as missing values. Hence, when the model is fit within PRESENCE, a value for the predicted occupancy probability will be outputted for these other units alongside the estimates for the units that were actually surveyed.

Sample Size Investigations

PRESENCE can be used to perform analytic-numeric investigations of sample size requirements. There is a 'hidden' option in PRESENCE that allows a summarised version of the data to be entered, with 1 row for each unique detection history and covariate combination, rather than a single row for each sampling unit. If our 'data' consists of all possible detection histories given the number surveys, and we calculate the expected number of units with each history, we can use PRESENCE to get asymptotic (large-sample) results for different sampling designs. This example is to demonstrate how you might go about this firstly for the situation where you only have a single group of units, and secondly where you have 2 groups of units and the intent to accurately estimate the difference in the probability of occupancy for the 2 groups.

One Group

Open the spreadsheet **Sample Sizes.xls** which can be found in the **Exercises** folder of the workshop materials, and select the sheet titled **One Group**. Follow the instructions on the worksheet to calculate the expected number of histories; specifying that $\psi = 0.63$, $p = 0.4$ and $s = 40$. Select and copy the cells A7:E22 (i.e., the detection histories and expected number of units with each history). Start a new project in PRESENCE, open the data input window and paste in the data. Set the number of sites to 16, leave the number of survey occasion as 5, but enter the number of surveys per season as 4. *When you save the file, when prompted if the last column is the frequency, select Yes*. Save the file with an appropriate name, then close the data input window. Select the file you've just created (you will get a warning that you can ignore), then hit the 'Click to view file' button to open the pao file in your default text editor. The image below should appear on screen.

The pao (data) file is simply a tab-delimited text file with a specified format. The main points of interest are indicated below, although this data file is a little bit different in that we've included an extra column for the expected number units with each history. If there were covariates in the data file, these would be inserted immediately after the integer indicating the number of covariates of each type. First the covariate name would be listed, then the covariate values, then the name of the next covariate and so on. Once you are familiar with the data file format, you can always create your own data files rather than using PRESENCE's data input interface. When you do so, you only need to include the information up to the line immediately before the project title; PRESENCE will append all of the information from the title line onwards when the project is created.

Complete the process to create the new project.

1 group, sample size, 4				
File	Edit	Format	View	Help
16	4			
1	1	1	1	0.64512
1	1	1	0	0.96768
1	1	0	1	0.96768
1	1	0	0	0.96768
1	0	1	1	1.45152
1	0	1	0	1.45152
1	0	0	1	2.17728
0	1	1	1	0.96768
0	1	1	0	1.45152
0	1	0	1	1.45152
0	1	0	0	2.17728
0	0	1	1	1.45152
0	0	1	0	2.17728
0	0	0	1	1.45152
0	0	0	0	2.17728
0	0	0	0	0.96768
0	0	0	0	0.96768
0	0	0	0	0.96768
0	0	0	0	0.96768
4				
site 1				
site 2				
site 3				
site 4				
site 5				
site 6				
site 7				
site 8				
site 9				
site 10				
site 11				
site 12				
site 13				
site 14				
site 15				
site 16				
1-1				
1-2				
1-3				
1-4				
12165				

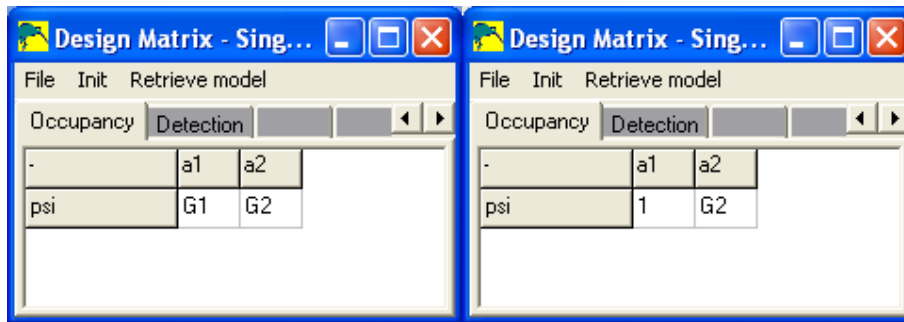
Fit a $\text{psi}(\cdot)\text{p}(\cdot)$ custom, single-season model and open the output. Note that the estimates of psi and p correspond exactly to the values used to generate the expected values, hence the method is unbiased. The reported standard errors indicate its expected value given a study with 40 units and 4 surveys. Clearly we've assumed perfect data here and in practice we can only have an integer number of units with each detection history. There may be other small-sample issues that may create some problems and simulation is a handy tool for assessing that.

Repeat the process with 80 and 200 sampling units and note the difference in the standard errors.

Two Groups

In the spreadsheet select the worksheet labelled **Two Groups**. Note that life has been made easier here for you with the probabilities and expected value calculations already inputted; you just need to input psi , p and s values for both groups. Specify your own values for psi and

p for each group, but make sure the difference in ψ is 0.2 and use p values in the range of 0.3-0.6. Initially, specify 30 units for each group. Once you have done this, the probabilities and expected values should be automatically calculated. Copy and paste the detection histories and expected values into a new project in PRESENCE as for the one group example. There are also 2 site-specific covariates to be included this time indicating each group. Copy and paste this into PRESENCE also. If you copy the covariate names, be sure to **paste w/cov names**. Finish creating the project, then fit the model $\psi(\text{Group})p(\text{Group})$ twice, using the 2 different design matrices for occupancy indicated below.



Open the output from these 2 models and describe the difference in the interpretation of the beta coefficient a_2 in each of them. What do these results indicate about your ability to precisely estimate a difference of 0.2 in the probability of occupancy with only 30 units per group?

Repeat this process again, but this time increase the total sample size to 120 with the following combinations of units in group 1 and group 2 respectively; 1) 40 and 80; 2) 60 and 60; and 3) 80 and 40. Comment on the results.

Multi-season models – a first example

In this example we are going to create a project with detection-nondetection data from multiple seasons (years) for the grand skink dataset referred to in the notes, then fit a range of models to investigate how important, and what effect, having a modified matrix between rocky outcrops (tors) has on each of the 4 parameters of interest.

Open the file **Grand Skinks.xls**, located in the **Data** folder of the coursework material. Data has been collected on 352 tors over a 5 year (the ‘seasons’) period, although not all tors were surveyed each year, with up to 3 surveys of each tor per year. The detection-nondetection data is in the correct format to be imported into PRESENCE. Not that the first surveys of all tors each year are in the same column, so the 15 columns are in 5 blocks of 3. There is also a site-specific covariate *Pasture* indicating whether the surrounding matrix is either predominately the modified habitat (farm pasture, *Pasture* = 1) or “native” grassland (tussock, *Pasture* = 0).

Begin a new project in PRESENCE, copy and paste the detection data and *Pasture* covariate. As this is mutli-season data, before saving the file, we need to tell PRESENCE how surveys occasions are in each of the 5 seasons. This is accomplished by simply listing the numbers (separated by a comma) in the text box labelled **No. Occ/season**. So here you would enter **3,3,3,3,3**. Save the data, then complete setting up the project as for the single-season models.

Data Input Form

File Edit Simulate Help

rows: 352 cols: 15 No. Occ/season: 3,3,3,3,3 No. Sites: 3

Presence/Absence data Site Covars

data	1-1	1-2	1-3	2-1	2-2	2-3	3-1	3-2	3-3
site 1	0	0	0	0	0	0	0	0	-
site 2	0	0	0	0	0	-	0	0	0
site 3	0	0	0	0	0	-	0	0	0

Specify number of surveys per season here. Note the change in the column labelling.

Once the **Results Browser** appears, select **Run>Analysis: multi-season**, which should bring up the following window. Note that it is a similar format to the single-season analysis, but with a different selection of models in the model box. Initially we will just use the first parameterization and use the other parameterizations in later examples. Note that there are no predefined models, and that all models have to be fit using the design matrix. Looking at the design matrix, previously we only have 2 named tabs in the design matrix window, and note that now we have 4, one for each of our parameter types. There is still only 1 real parameter (row) for occupancy as under this parameterisation we are only estimating the probability of occupancy in the first season. There are 4 real parameters for colonization; there are 5 seasons of data so 4 between-season opportunities for the species to colonize a location. Similarly, there are 4 real parameters for extinction probabilities. Finally there are 15 real parameters for detection, 1 for each survey occasion.

Setup Numerical Estimation Run

Title for Analysis: TITLE

Model Name: psi,gamma[],eps[],p[]

Fix Parameters: No Parameters Fixed

Model parameterization

- ☒ Init occ,local colonization, extinction, detection
- ☐ Seasonal occupancy and colonization, detection
- ☐ Seasonal occupancy and local extinction, detection
- ☐ Seasonal occupancy (eps=1-gam) and detection

Options

- ☐ Set function evaluations
- ☐ Bootstrap V-C matrix
- ☐ Assess Model Fit
- ☐ Use simplex algorithm for starting values
- ☐ Set max estimates to print
- ☐ Use Complimentary-log-log link for Psi

Cancel Run OK to Run

Different parameterizations available for the multi-season model.

The first model we are going to fit is $\psi(\cdot)$, $\gamma(\cdot)$, $\epsilon(\cdot)$, $p(\cdot)$, i.e., each of our parameters are constant across time and space. This is actually the default model when you open the analysis window so here we just have to rename the model, then press 'Ok to Run'. Confirm the model then open the output. Note that the first part of the output is very similar to the single-season output, with the main exception being that there are now 2 additional design matrices, one for colonization (γ) and one for extinction (ϵ) probabilities. Focusing on the estimation part of the output, first there are the beta parameters that are reported on the logit-scale, and their variance-covariance matrix. This is followed by the real parameter estimates. From this model we would therefore could that; 1) the probability of occupancy in the first year was 0.39; 2) between all seasons, the probability that skinks colonize a previously unoccupied rocky outcrop is 0.07; 3) between all seasons, the probability that skinks go locally extinct from an occupied rocky outcrop is 0.10; and 4) given an outcrop is occupied by skinks, the probability of detecting skinks in a single survey is 0.69.

Below the real parameter estimates, some derived estimates are reported. These are calculated using some equations that shall be covered later, but briefly the derived estimates are the probability of occupancy in years 2-5, and then an occupancy-based population growth rate that are calculated as the ratio of successive occupancy estimates. From these estimates one might conclude (based upon this particular model) that the system appears relatively stable, as the derived probabilities of occupancy are very similar and the λ s are approximately 1.

pres5174.tmp - Notepad

File Edit Format View Help

Untransformed Estimates of coefficients for covariates (Beta's)

			estimate	std.error
A1	:occupancy	ψ_{11}	-0.428416	(0.130723)
B1	:colonization	γ_{11}	-2.613299	(0.186239)
C1	:local extinction	ϵ_{11}	-2.197056	(0.201272)
D1	:detection	$p[1-1]$	0.796169	(0.106700)

Variance-Covariance Matrix of Untransformed estimates:

	A1	B1	C1	D1
A1	0.017089	-0.004710	-0.000867	-0.002854
B1	-0.004710	0.034685	0.008093	0.003774
C1	-0.000867	0.008093	0.040510	0.007043
D1	-0.002854	0.003774	0.007043	0.011385

Individual Site estimates of Psi:

Site	Survey	Psi	Std.err	95% conf. interval
1 site 1	1	1-1: 0.3945	0.0312	0.3352 - 0.4571

Individual Site estimates of Gamma:

Site	Survey	Gamma	Std.err	95% conf. interval
1 site 1	1	1-1: 0.0683	0.0118	0.0484 - 0.0855

Individual Site estimates of Eps:

Site	Survey	Eps	Std.err	95% conf. interval
1 site 1	1	1-1: 0.1000	0.0181	0.0697 - 0.1415

Individual Site estimates of p:

Site	Survey	p	Std.err	95% conf. interval
1 site 1	1	1-1: 0.6892	0.0229	0.6427 - 0.7321

Beta parameter estimates.

Real parameter estimates.

pres5174.tmp - Notepad

File Edit Format View Help

Site	Survey	Eps	Std.err	95% conf. interval
1 site 1 1	1-1:	0.1000	0.0181	0.0697 - 0.1415

Individual Site estimates of p:

Site	Survey	p	Std.err	95% conf. interval
1 site 1 1	1-1:	0.6892	0.0229	0.6427 - 0.7321

=====

DERIVED parameters - psi2,psi3,psi4,...

Site	psi(t)	Std.err	95% conf. interval
1 site 1 psi(2):	0.3964	0.0264	0.3447 - 0.4481
1 site 1 psi(3):	0.3980	0.0254	0.3482 - 0.4478
1 site 1 psi(4):	0.3993	0.0271	0.3463 - 0.4523
1 site 1 psi(5):	0.4004	0.0299	0.3418 - 0.4589

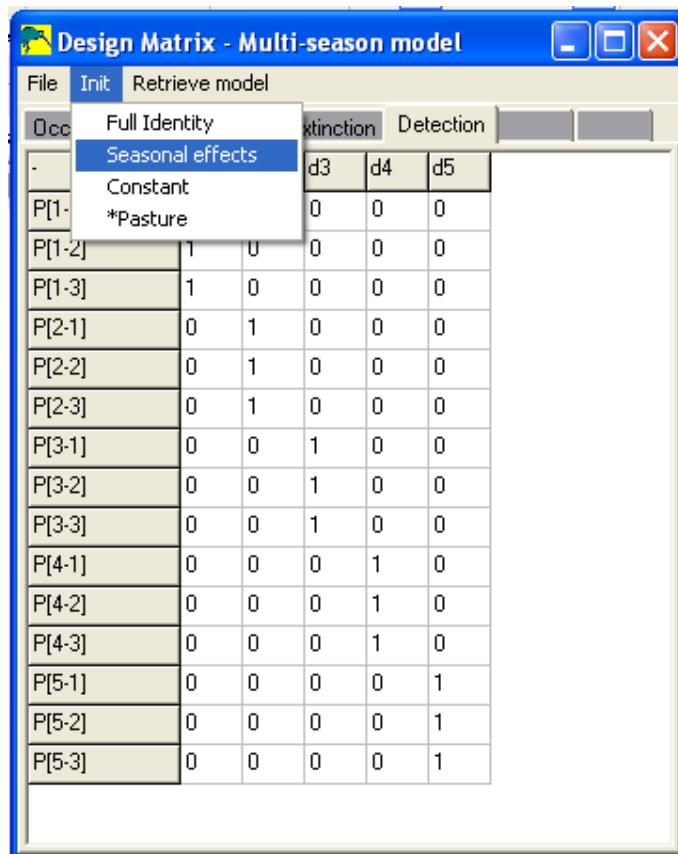
DERIVED parameters - lam2,lam3,lam4,...

Site	lam(t)	Std.err	95% conf. interval
1 site 1 lam(2):	1.0048	0.0280	0.9499 - 1.0597
1 site 1 lam(3):	1.0040	0.0231	0.9588 - 1.0492
1 site 1 lam(4):	1.0033	0.0191	0.9659 - 1.0407
1 site 1 lam(5):	1.0027	0.0157	0.9719 - 1.0336

CPU time: 1.0 seconds

Derived parameter estimates.

Now, fit the model $\text{psi}(\cdot), \text{gamma}(\text{year}), \text{eps}(\text{year}), \text{p}(\text{year})$, that is, we are allowing colonization, extinction and detection probabilities to be different in each year. The design matrices for colonization and extinction can be defined by selecting **Init>Full Identity** in the design matrix window (there are also other parameterisations possible that will give the same model). For detection probability, we are assuming that detection probability varies among years, but within years the probability of detection is constant. A shortcut to defining this type of model for detection is available in the Init menu with the **Seasonal effects** option (this option is unavailable for the other design matrices).



Looking at the results, the estimated probability of; 1) occupancy in the first year is 0.38; 2) colonization is 0.12, 0.01, 0.07 and 0.10 for each of the between year periods respectively; 3) extinction is 0.07, 0.07, 0.14 and 0.17 for each of the between year periods respectively; and 4) detecting the skinks in a single survey is 0.70, 0.65, 0.69, 0.84 and 0.66 in each of the 5 years respectively.

The next step in this example is to consider how much evidence is there for the importance of the *Pasture* covariate as a predictor for the occupancy-related parameters. We're going to fit a range of models representing different hypotheses about how we believe pasture might influence occupancy and its vital rates. Our model set is generated by considering the different combinations of these hypotheses.

Parameter	Hypothesis
Occupancy	- Is the same for all outcrops
	- Is different for outcrops surrounded by pasture
Colonization	- Varies in time, does not depend upon intervening matrix
	- Varies in time, intervening matrix has an effect that is consistent each year
Extinction	- Varies in time, does not depend upon intervening matrix
	- Varies in time, intervening matrix has an effect that is consistent each year

Exercise 3

1. Define a candidate set of models based upon these hypotheses. For all models allow detection probability to vary among years, but be constant within years, and allow

detection to be different dependent upon the surrounding matrix with the effect being constant for all years, i.e., a $p(\text{year} + \text{Pasture})$ model.

2. Fit these models in PRESENCE.
3. Determine the amount of evidence for each hypothesis.